THE OCCURRENCE OF THE AUSTRALIAN PILCHARD, *SARDINOPS NEOPILCHARDUS* (STEIND.),* AND ITS SPAWNING SEASON IN NEW SOUTH WALES WATERS, TOGETHER WITH BRIEF NOTES ON OTHER NEW SOUTH WALES CLUPEIDS.

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(Plate xi.)

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It is frequently stated that nothing is known of the shoals of pelagic fish (including the pilchard) in Australian coastal waters. As this statement is certainly incorrect for part of the coast of New South Wales at least, and as the matter of the distribution of this species may be of considerable commercial importance in the near future, the following notes are set out on the discoveries which have recently been made, despite the inefficient means of ocean investigation at our disposal.

During the past five years, whilst accumulating data on the Biology and Hydrography of the coastal waters of New South Wales, the eggs and larvae of the pilchard have been discovered and identified, a piece of work involving a considerable constancy of effort at sea in a small boat. And this has not been confined to one year, or been a matter of accident. The occurrence of these eggs and larvae has been deliberately followed week by week, and at more than one place (at Port Stephens, off Broken Bay, off Port Jackson, and off Port Hacking), and the duration of the spawning season elucidated.

The New South Wales pilchard, *Sardinops neopilchardus* (Steind.) is a medium-sized species of the herring group found at certain seasons in coastal waters in enormous shoals, after the habit of members of this group. Systematists have indicated the resemblance of this species to the true pilchard, *Sardinia pilchardus* of Europe, as well as to *Sardinops coerulea* of the North Pacific Coast of America (now captured in enormous numbers in the great Californian "sardine" industry), to *Sardinops sagrax* (Jenyns) of the coast of Peru, and to *Sardinops melanosticta* (Temminck and Schlegel) of Japan.

The Australian species is not confined to New South Wales waters. It has been recorded as far south as Hobart in Tasmania, and shoals have been recorded as occurring in Tasmanian waters (Johnston, 1882). In Southern Victoria it was noted at an early date, McCoy recording that hundreds of tons were captured in Hobson's Bay as far back as 1864–66 (in August). It has also been taken as

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* *Sardinops neopilchardus* (Steind.) see Whitley (1937); *Sardinia neopilchardus* (Steind.) see McCulloch (1919); *Clupea neopilchardus* Steindachner, *Denkschr. Akad. Wiss. Wien*, xli, 1, 1879, p. 12.

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far north as Hervey Bay in Queensland. The species is also abundant 1,000 miles eastward, on the New Zealand coast, where it has been systematically fished during the winter.

To return to the Australian coast, we find that steady reports of pilchard shoals have been made since the first records. In 1879 Macleay quoted McCoy's descriptions of how in three successive years (1864–66) in the same month of the year (August) thousands of specimens appeared in Hobson's Bay, southern Victoria, and hundreds of tons were sent to the country markets. "Ships entering the bay passed through closely packed shoals of them for miles." Macleay adds that on the coast of New South Wales it is June and July which are the months of great frequency, but that it is not easy to fix the time within a few weeks. The shoals were described as enormous, covering miles of sea, and accompanied by flights of birds and numbers of large fishes. The shoals were generally observed from one to three miles from the land, and always proceeding in a northerly direction. Probably these records of Macleay are reliable by reason of his knowledge of the subject, but it will be seen later that fishermen frequently make mistakes in their diagnosis of shoals.

Stead, as far back as 1911, in referring to the possibilities of pelagic fisheries, describes the use of a purse seine net, and remarks that records of prodigious shoals on the New South Wales coast have frequently been made. It is also stated that millions have been washed up on the beach at Yamba, Clarence River. Whitley (1937) quotes the date of this occurrence as May, 1911, and this is interesting since a shoal, reputed to be *S. neopilchardus*, came close inshore at Yamba in May, 1937, whilst the author was at that place.

In his previous work (1908) Stead remarks that the shoals are usually of greatest magnitude during *spring* and early *summer* and from his personal experience, in September.

Before touching on the more definite findings which have been made by myself whilst working with the research yacht "*Thistle*", it will be useful to indicate the records of pilchard shoals which have been sent in by the State Fisheries Department's Inspectors stationed along the coast of New South Wales.

Returns are sent in monthly from the fisheries inspectors. From these it would appear that pilchards are seen regularly every month over a long season at some stations. Occasionally notes of great shoals are present.

Records of occurrence of pilchards off coast of N.S.W. by Inspectors of Fisheries.

	1934	1935	1936-37
Tweed River ...	Apr.-Sep.	Apr.-June.; Sep., Nov.	—
Richmond River	—	—	Aug.,1936-Jan.,1937
Manning River..	May-Sep.	Apr.-Aug.	May-Aug.,1936
Wallis Lake ...	May-Sep.	Mar.-Nov.	All year
Port Stephens ..	Aug.-Sep.	—	Jan.-Feb.,1936; Oct.,'36-Apr.,'37
Lake Macquarie	—	—	Sep.,1936-Apr.,1937
Terrigal	—	Mar.-May, Aug.-Nov.	—
Botany Bay	May.-Sep.	—	—
Port Hacking ..	May-Sep.	Mar.-June	July-Nov.,1936; Mar.-Apr.,1937
Lake Illawarra..	—	—	Oct.,1936-Mar.,1937
Clyde River	—	Oct., Nov.	Sep.,1936-Mar.,1937

The problem of the correct interpretation of these reports is twofold. Of course definite captures of pilchards, from which authoritative diagnosis of specimens has been made, would put certain records out of all doubt. But unfortunately these seem few and are, on the whole, isolated cases, and in any case they supply little or no indication of the length of time the pilchards remained in quantity at the place of observation.

From the point of view of industry, one wants to know for how long and in what sort of quantity the shoals of pilchards remain within any certain limited area of coastal water. A fishery cannot be built up on occasional shoals of pelagic fish whose occurrence might be limited to a week or a few weeks every year, and at varying times.

Some of the Inspectors' reports leave no room for doubt and are extremely valuable in conjunction with our findings. Thus on more than one occasion quantities of pilchard have been driven into the surf by tunny and kingfish and picked up in baskets full. They have also frequently been taken inside snapper when schools were observed.

One Inspector reported that the pilchard worked in towards the coast in April, May and June and described examination indicating that the fish were in roe. He adds that they usually come to the surface at nightfall and are seen by their "phosphorus" (luminescence).

Several reports refer to the tunny, Spanish mackerel, and bonito coming with the pilchard, also to pilchard having been found in salmon and jew-fish.

A more serious criticism applies to the records from fishermen on the coast—the shoals seen from the shore or even from a boat and said to be pilchard may be of some other clupeid species. This criticism receives strong support from the fact that on two occasions within the last six months samples of shoaling clupeids which have been sent in to us by fishermen as pilchards have turned out to be (1) the Maray, and (2) the Sandy Sprat. It is, incidentally, difficult in this connection to see how any safe records could be made from the air unless specimens were being captured at the same time.

One answer to the question asking what amount of absolutely reliable knowledge exists concerning the duration of the occurrence of pilchards in shoals in any one area off our coasts, seems to us to turn on our discoveries of pilchard eggs and larvae. Apart from the published evidence that between May and September shoals of pelagic fish occur, not unlike pilchards in size, and from the capture now and then of fish from these shoals, putting their isolated occurrence as beyond question, there is no real published evidence of continuity. And there was no evidence of the duration of the spawning season before the publication of the paper by Dakin and Colefax (1934).

The first information regarding the spawning places of our pelagic fishes came from the discovery of clupeid eggs in the plankton taken off the coast during the winter months. About the same time, the early stages of clupeid larvae appeared in the catches. Now the recognition of the pilchard eggs in the catches from the coastal waters off Broken Bay, off Port Jackson, off Port Hacking and off Port Stephens, is linked up with the identification of the clupeid larvae (of various stages) which were associated with them.

The capture of clupeid larvae presented more than the usual problem of identification for, whilst the recognition of the larvae as those of a clupeid was not difficult, there are five or six species of Clupeids off this coast, of which the young stages are likely to be extremely similar. None of these early stages had ever been obtained before, and it must be remembered that, since no commercial fishing of these species is taking place even now, no hints for identification could be obtained from the presence of spawning adults. The Clupeids in question are the Pilchard, *Sardinops neopilchardus* (Steind.); the Blue Sprat, *Stolephorus robustus* (Ogilby); the Sandy Sprat, *Hyperlophus vittatus* (Castelnau); the Maray, *Etrumeus jacksoniensis* Macleay; the Herring, *Harengula castelnaui* (Ogilby); and the Freshwater Herring, *Potamalosa novae-hollandiae* (Cuv. and Val.).

It was presumed that, although unlikely, the freshwater herring might produce eggs in the estuaries, which could be carried out to sea. Since the first investigation was made, specimens of this fish with mature reproductive organs have been obtained. They were captured in the Clarence River near Grafton (about 60 miles inland from the sea). The spawning season of this fish is evidently in July and August. It is extremely probable that these eggs are not pelagic at all, but laid on the bottom or attached to other objects. The ovarian eggs in the specimen examined were 1 mm. in diameter.

The method adopted for identification of the larvae was to continue their capture and to collect together a series from which some definite counts of fin rays and vertebrae could be made. This postulated the capture of stages sufficiently developed to indicate certain adult characters useful for this means of diagnosis. Whilst the existing systematic literature gives on occasion the number of fin rays in the fins, the counts often appear to have been made on a single specimen or one or two from the same locality and taken at the same time. Counts of the number of vertebrae are either missing or very unreliable. It was necessary, therefore, to re-examine a number of specimens of the Clupeids concerned in order to obtain more accurate information. The figures given in the table below show the result of this investigation. These figures do not exclude a wider range of variation—examination of a large number of individuals of each species would be required in order to determine such range with absolute certainty. Indeed, there may be different races of the species in Australian waters. With this indication of the need for caution it will be seen that the characters chosen were such as would put the recognition beyond the limits of experimental error.

	Dorsal Fin. Number of Rays.	Anal Fin. Number of Rays.	Number of Vertebrae.	
			Our Counts.	Counts Stated by Other Observers.
Pilchard	18	18	50	45 and 49
Blue Sprat	12	10–11	47	45
Sandy Sprat	15	19	47–48	46
Maray	19–21	11	53	
Herring	16–18	18–19	41	39
Freshwater Herring ..	15–16	15–18	44–46	46

In the matter of the Herring, *Harengula castelnaui*, the figures for the fin rays given by the original author of the species, Ogilby, are Dorsal 17–19, and Anal 19–21. We have not obtained the highest of these figures in any specimen examined, but it is noteworthy that the number is only 16 for a specimen from the Clarence River and 18 for a specimen from Lake Illawarra. There is remarkable difficulty in obtaining specimens of this fish, although it must be abundant.

The first character to be noted in the small larvae is that the number of vertebrae is 50. Actually the number in front of the anus varies during development—a character noted in other parts of the world for certain Clupeids. It will also be noted (see Dakin and Colefax, 1934) that the dorsal fin gradually moves forward during development.

On the basis of vertebral counts one might, at the outset, eliminate all but the Maray. Actually, however, the vertebral numbers recorded for the Blue Sprat and the Sandy Sprat were regarded as close enough to make other identification characters essential for a reliable diagnosis.

Now, even in larvae of 18 mm., the number of fin rays in the anal fin is sufficient to cut out the Blue Sprat and the Maray. At any larger size the number of fin rays in the dorsal fin cuts out the Sandy Sprat and the Freshwater Herring. The fin rays alone might leave us unable to distinguish between an early stage of the Pilchard and one of the Herring, although, the latter larva not yet having been identified, it is impossible to define its characters. However, the number of fin rays and vertebrae, taken together, leave the result without doubt, for the number of vertebrae in the Herring is the lowest of all the Clupeids concerned.

One reason still to be mentioned for a careful re-examination of the data given above was the discovery of pilchard larvae off the entrance to Broken Bay. These were obtained much earlier in the year than those which were first recognized by us from the coast off Port Jackson, and they presented a slight difference in appearance due to the fact that a conspicuous swelling of the swim bladder was to be noted. It is now assumed that this difference was an effect of the methods of capture: the larvae had previously been taken in surface waters, but the Broken Bay haul was pulled up rather suddenly in a net used for a bottom haul, albeit the depth fished could not be great at this locality owing to the shallowness—10 fathoms.

Comparison of all our larvae set aside as possible pilchard now shows that there is no doubt of the identification. The fact that clupeid eggs formerly identified as pilchard were found in October as well as in the winter months beginning with May led us to a careful measurement of a considerable number of eggs. The range of diameters was exactly the same for the samples concerned.

It is clear, therefore, that the spawning of the pilchard which takes place off the coast of New South Wales occurs over a long season. We can also add that the larvae occur between places as far apart as Port Stephens and Port Hacking, and, since eggs were discovered in large numbers at the latter place, spawning must occur throughout this length of coast at least. A clear indication of the peak of the season, as of the detailed understanding of the length of time the fish may be captured at any one place in quantity, will await the further investigation of an ocean-going research vessel.

Small pilchard larvae varying between 8 and 20 mm. in length have now been taken in the months of April, May, June, July, August, September, October and November. In our first paper on the eggs of the pilchard, we referred to catches made in June, July and August. Since then we have obtained large catches of eggs at the beginning of May (at Port Hacking), and some very large catches in October (off Broken Bay). Since, however, we have obtained larvae in April, it might be assumed that some spawning takes place in February. Possibly eggs may be taken in every month of the year. We have now taken eggs from March to October, with large catches in May, July and October.

In a report of the Marine Station of Portobello, New Zealand, for the year ending March, 1936, it is stated that pilchards are found throughout the year, and it is assumed, from the fact that all sorts of sizes appear, that the breeding season is an extended one. There is, however, no mention of scientific evidence. Another reference gives November and December as the spawning season.

It is interesting to make some comparison with the Californian pilchard whose habits are now comparatively well known. According to Dr. Frances

Clark, the maximum area of spawning of the Californian pilchard occupies a region 200 miles north and south and 100 miles in width, although a general spawning takes place over 1,600 miles of coast (measured north and south). The spawning season extends from February to August with peaks in April and May. But as this is the Northern Hemisphere, the months correspond, in Australia, to the period from August *through the summer to February*, with a peak in October and November. It is difficult for us to make accurate comparisons because, though we have taken a great haul of eggs as late as October, our work at sea has been least intense in summer owing to various difficulties associated with our oceanographical work.

It would appear, however, that the spawning season of the Australian pilchard off the coast of New South Wales definitely extends over quite as long a period as that of the Californian pilchard. It has been noted above that spawning pilchards have been recorded at Portobello, New Zealand, in November and December. The latitude of this place is considerably south of Sydney. Another New Zealand reference (Report on Fisheries, N.Z., 1933) states that pilchard eggs were taken during December and January by tow-netting. It is interesting to note that whilst the European pilchard has been observed to spawn off the English Channel in the summer months of July and August, the same species spawns in the Mediterranean during the winter. In this case, however, the spawning season lasts practically the whole year, with a maximum from December to February—i.e., a maximum in the three *winter* months.

Strictly speaking, the term "Sardine" should be confined to the young of the pilchard. In California it is used for the adult pilchard as well. Now one of the most interesting discoveries bearing on the occurrence of pilchard eggs and larvae in New South Wales waters was the catching of a shoal of small sardines inside the estuary of the Hawkesbury—well up in the Pittwater to be exact, on 3rd October, 1936. The specimens (see Plate xi, fig. 1) were obtained with a hand net by my Research Assistant, Miss I. Bennett. At 4 o'clock in the afternoon (low water 3.57 p.m.) a small shoal of these young fish, which must have contained millions, appeared along the beach. The visible area extended about 400 feet in the direction along the beach and 50 feet outwards. This was merely the area where they were breaking water. The water ranged from a foot in depth to about ten feet. The fish were crowded together so that a scoop with a bucket was like scooping out the contents of a fishing net. The length of the specimens obtained varied from 38 mm. to 56 mm. Since these individuals might be regarded as two–three months old, the observations indicate that considerable numbers of eggs were spawned off our coast in June–July, 1936, fitting in excellently with our captures of eggs and larvae in 1932, 1933 and 1934. This discovery also indicates how some of the early stages may enter into inshore estuarine waters. It is still unknown to what extent this migration is typical of the life-history of our fish and, although we have been specializing for several years on the planktonic and post-larval stages, it is significant that we have never observed such a shoal of small sardines in these inshore waters before. The difficulty of the non-systematist distinguishing between the small fish species which are abundant in the same localities renders observations by fishermen once again of very little count. The discovery was, in any case, a very valuable one in providing further support for the diagnosis of the pilchard larvae.

It is noteworthy that in 1935 we sailed through shoals of pilchard at the entrance to Broken Bay in the month of May (four consecutive weeks). The fish were packed in shoals over an area of two or three square miles, often breaking

water and making the sea surface look as if struck by gusts of wind. Large numbers of gulls and terns were diving after the fish.

In 1937 nothing of this kind appeared at Broken Bay during the same period, although odd eggs and pilchard larvae were being taken. But large numbers of the eggs were captured at Port Hacking during these weeks, and the activity of the gulls was noted off Port Jackson at the same time.

On the 18th of July (that is, about two months later) shoals of fish appeared at Broken Bay, and with them the gulls and terns performing the same feats of diving. Plankton catches were made and the results were striking; we had one of the largest hauls of pilchard eggs we had ever taken. The sequence of dates seems worthy of record.

It is worth recording here that shoals of Maray were seen and fish captured near the entrance of Sydney Harbour (off the Quarantine Station) in the month of August. These fish had undeveloped reproductive organs. They averaged 16 centimetres, say 6½ inches, in length. It is rather surprising to find in McCulloch's "Fishes of New South Wales" (1934) a statement to the effect that the Maray is a southern fish, not common in New South Wales waters. It would appear that this is decidedly not the case.

Shoals of Sandy Sprat, 3½ inches in length, were about the entrance to Port Jackson in June (1937). Specimens of these were captured by fishermen and sent in to market where they were sold as Sardines! The reproductive organs were on their way to maturity.

Finally, catches of Freshwater Herring were sent from Grafton on the Clarence River to the Sydney markets in July (1937) and sold as Herring, without any qualifying adjectives. These were absolutely mature, the gonads being completely ripe. There is little or no evidence to indicate that these fish deposit their eggs in ocean water, even in the estuary mouths, and it would appear very likely that the eggs of this Clupeid are demersal.

The locality of capture was actually twenty–thirty miles up-river from Grafton. Analyses of the river water at Grafton at the time showed that the salinity was only 0·54‰ at low water and 1·57‰ at high water as compared with 35‰ for ocean water.

Confirmation of the above in regard to the Freshwater Herring is also to be obtained from the fact that McCulloch (1917) noted that specimens taken from fresh water in the Hastings River in March, 1916, had developed milt and roe. The length of these fish was 8 inches; ours from Grafton ranged from 10 to 12 inches in length (Plate xi, figs. 3, 4).

Summary.

1. Further observations are set out concerning the diagnosis and identification of the larvae of the Australian Pilchard taken in New South Wales coastal waters.

2. Evidence is produced to show that the breeding season of the Pilchard extends through a very long period and that probably eggs are obtainable in every month of the year.

3. A shoal of young sardines, length 38–56 mm. and probably only 2–3 months old, was investigated, occurring in October inside the estuary of the Hawkesbury River.

4. Shoals of Sandy Sprat occur close in to the coast and enter the estuaries in June. The gonads in that month are approaching maturity.

5. Shoals of Maray have entered Sydney Harbour in August-September. The fish had undeveloped reproductive organs—probably spent.

6. The Freshwater Herring in the fully mature state has been taken at Grafton, Clarence River, in fresh water. The eggs are very likely demersal.

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DESCRIPTION OF PLATE XI.

Fig. 1.—Part of catch of Sardines (young of pilchard, *Sardinops neopilchardus* (Steind.)), from Pittwater, New South Wales.

Fig. 2.—Pilchard larva 17 mm. in length (stained by Van Wijhe method).

Figs. 3, 4.—Mature Freshwater Herring (*Potamalosa novae-hollandiae*) from the Clarence River, Grafton, N.S.W. 3, Male; 4, Female.